UNITED STATES DEPARTMENT OF AGRICULTURE
Rural Electrification Administration
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ENGINEERING NOTES CONCERNING REA-FINANCED RURAL ELECTRIC SYSTEMS

Introduction

The following several paragraphs are intended to furnish engineering background information of the REA program in a condensed form. Because of the wide range of subjects covered, few details are included. It is hoped that this information will facilitate a better understanding of discussions and review of technical publications.

The Rural Electrification Administration (REA) was established by executive order in 1935, which preceded the passage of the Rural Electrification Act of 1936. REA is a lending agency of the United States Department of Agriculture. It makes loans for the purpose of financing electric systems in rural areas. In 1949 the RE Act was amended to provide for loans for telephone service to rural areas. The telephone program will not be discussed here. Loans bear 2 percent interest and are repaid over a maximum period of 35 years. During the past 21 years about $3\frac{1}{4}$ billion dollars have been advanced to REA borrowers for the construction of more than 1,300,000 miles of electric line which serve over 4,000,000 farms and rural establishments. About 95 percent of the nation's farms have central station electric service, of which 55 percent are served by REA borrowers and 45 percent are served by private power companies or other organizations.

It should be kept in mind that REA itself does not construct or operate any electric facilities but makes loans to organizations which are responsible for the construction and operation of their systems. Most of the REA borrowers are organized as cooperatives incorporated under State laws; however, some loans have been made to other types of organizations including municipalities, public power districts and private companies. REA furnishes

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assistance and guidance to its borrowers in engineering, management, accounting, and legal matters. Its main functions are to lend money and assure repayment through appropriate loan-supporting activities.

Rural Areas and Farm Equipment

In order to understand the nature of rural electric systems, it should be noted that the farmers in this country live on their farms. The rural towns are primarily trading centers for the farmers. A large percentage of these towns were receiving central station power prior to the establishment of REA and therefore only a few of the very small towns and villages are supplied power by REA borrowers. The distribution systems and their loads are therefore predominantly rural.

Because of the widespread use of tractors equipped with a power drive on the farms, which are also used for powering many of the farm machines requiring considerable horsepower for a few hours during the year, the use of large electric motors for such purposes is limited. Tractors and other internal combustion engines are often used for powering large farm machines with low annual operation in place of electric motors. The largest motors for pure agricultural operation are for irrigation pumps. Most electric motors for powering irrigation pumps are from 15 to 40 horsepower. The small electric motors of less than 10 horsepower are used extensively on farms for refrigeration, milking machines, water systems, and for powering other small farm machines and tools.

The use of electricity on farms is continually increasing as farmers add more appliances and equipment to perform their household and farm tasks. During 1955 the average monthly usage per farm served by REA borrowers was 245 kwh at an average cost of about 2.3 cents per kwh. This usage has doubled in the past seven years.

Secondary and Services

Since primary distribution lines are brought to within a short distance (approximately 50 to 500 feet) of the load center of each farm, secondary or service leads are short compared to the usual urban or residential distribution system. Three-wire single phase service of 120 and 240 volts is the standard service arrangement. One service wire is grounded; the other two wires are 120 volts above ground. A comparatively small percentage of farms that require three-phase service primarily for irrigation pumps or other large motors are furnished 240 or 480 volt three-phase service.

Distribution Transformers

Because of the relatively large distance between rural consumers, a separate distribution transformer is usually provided for each farm. In some instances it is possible to serve more than one consumer with a single transformer but this is the exception. It is estimated that there are 1.25 rural consumers per transformer on systems financed by REA. Transformers for single phase service vary from 1½ kva to 25 kva, with 3 and 5 kva being the most common sizes. All distribution transformers are pole mounted. Transformers, including large substation transformers, are not placed in housings or vaults.

Primary Distribution Lines

Practically all distribution systems in rural areas are radial with several three-phase multigrounded neutral feeders or lines emanating from the substations. As the distance from the substation increases, the loads decrease and only two phase wires and a neutral (V-phase) or a single phase wire and neutral are continued. The majority of mileage is in single phase lines. Taps or extensions from the "main" line are generally single phase.

The most common voltage for rural distribution lines is 7200 volts phase to ground or 12,470 volts phase to phase. A few systems use 6600 or 7620 volts as a standard voltage. In the past several years a considerable

amount of 14,400 volt distribution lines has been constructed in sparsely settled areas where distances between farms are great. Line-to-line voltage on multiphase lines is therefore 24,900. There are some older lines in rural areas operating at 2400 volts and other voltages although this is not common.

Substations

Distribution substations are required to transform the power from the existing source or transmission line to the distribution voltage. The most common types of distribution substations are 33 or 69 kv (high side) and 7.2/12.45 kv (low side) with from 2 to 6 distribution feeders. Substation capacities in the range of 500 to 1500 kva are most common. Voltage regulators and circuit breakers are generally used on the low side with fuses and disconnects on the supply side. Most substation transformers are single phase and one spare transformer is usually provided. Substations may be owned by the REA borrower or its power supplier.

Transmission Lines

Transmission lines serving distribution substations may be owned by the REA borrower or its power supplier. The most prevalent transmission line voltage is 69 kv although there is considerable 34 kv and lesser amounts of 22 and 44 kv. In a few instances 115 kv lines serve distribution substations although generally 115 kv and above is transformed to an intermediate voltage before serving a distribution substation. Wherever possible loop feed is used on transmission lines but in many cases substations are served from a single transmission line. Practically all of the transmission lines financed by REA are of wood pole construction. The lower voltage lines are generally single pole crossarm construction while 115 kv and above (and some 69 kv) are H-frame structures. Overhead ground wires are usually provided. Practically all of the transmission being constructed at the present time uses ACSR conductor rather than copper type conductor.

Power Supply

Power sources and power supply in rural areas are one of the most important considerations in providing electric service to rural areas. At the present time approximately 43 percent of the power requirements of REA borrowers are furnished by power companies, 32 percent from Federal agencies, 8 percent from other public agencies, and 17 percent generated by the borrowers. In areas where wholesale power was not available or not available at the reasonable cost, REA has made loans for the construction of generation facilities. A number of borrowers have constructed steam, internal combustion, and hydro-electric generating plants. In general, as compared with the industry, these plants can be considered small in size; for example, Diesel plants in the range of 100 to 10,000 kw, steam plants 10,000 to 50,000 kw (with a few plants exceeding this figure), and hydro plants from several hundred to 15,000 kw.

The cost of wholesale power is probably the largest single item of expense in operating a rural distribution system. Therefore, in order that distribution systems be economically feasible, power costs must be as low as possible. Wholesale power costs vary widely in different parts of the country. Average wholesale power costs to REA borrowers have been reduced from 1¢ a kwh in 1941 to 7.4 mils in 1955.

Distribution System Design

Many factors must be considered prior to the actual design of a distribution system. Studies are made of the area to be served, the type of farming, and type of electrical equipment the consumers will use. Based on these studies and trends of past and present load growth, estimates of power requirements for 2, 5, and 10 years in the future are made. Kw demands and voltage drops for the proposed system are then determined from these kwh estimates. Distribution lines are generally designed for a maximum voltage drop of 7 percent on the primary line without the use of line voltage regulators. Distribution lines in rural areas must be designed at low cost to be economically feasible. High strength conductors, long spans, and vertical configuration of conductors without the use of crossarms on

single phase lines, are some of the means used to lower costs. Structure designs have been simplified and standardized to minimize both engineering and construction costs. Both distribution and transmission lines are designed to meet requirements of the National Electrical Safety Code. Some state and local governments have codes which may be more stringent in which case their requirements must be met. REA borrowers engage consulting engineering firms for the design and supervision of construction of their systems. REA provides standard construction drawings, specifications, material lists, contract documents, and other guides to its borrowers and their engineers.

Distribution and Transmission Line Construction

Construction of lines may be performed by contractors who have awarded a contract for the construction of a specific project, or by the borrower's own crews on its payroll. Most of the initial construction of borrowers' systems was performed by independent contractors. However, in recent years where line extensions, additions and changes have been the major portion of the work, borrowers have utilized their own forces to a greater extent.

Probably the most important single factor in reducing construction costs was the establishment of construction on a unit basis. For example, separate units are furnishing and installing individual units or specified amounts of (1) poles, (2) pole top assemblies, (3) conductor, (4) guys and anchors, (5) transformers, and (6) clearing of right-of-way. The contractor's bid is made up on the basis of the sum of individual units. Since the quantity of units specified by the engineer are approximate, the contractor is paid on the basis of units actually installed. This method provides a means of taking bids on construction before the final design and staking has been completed, as well as providing an equitable means of computing costs of changes or additions which may be required as the work progresses.

In the construction of rural lines, the recommendations of the manufacturers concerning the installation and use of their material and equipment are followed. The various manufacturers publish engineering data concerning their material and equipment. For example, the conductor manufacturers publish data on the staking of line and installation and sagging of conductor.